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Stabilization Pond Site Evaluation

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STABILIZATION POND SITE EVALUATION

BY

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STABILIZATION POND SITE EVALUATION

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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INTRODUCTION

The number of sewage stabilization ponds has increased considerably in South Dakota and throughout the nation since they were first introduced in the late 1920's and early 1930's. The relatively low initial cost, low costs of operation and maintenance, plus the satisfactory results which have been obtained, have made stabilization ponds a means for not only treating small town domestic wastes, but also for secondary, tertiary, industrial, and farmyard waste treatment.

At the present time there is an increasing emphasis on pollution control and water quality standards. The results of current legislation, standards, and public opinion may require municipalities, industries, and others to treat their wastes to meet certain criteria. Because of their advantages it is foreseen that one of the major methods of satisfying these treatment requirements is through the use of stabilization ponds.

Any waste which is placed on land will in some manner affect the surrounding environment. The problem becomes one of determining the extent in which the environment can acceptably be changed. A stabilization pond is relatively permanent once it has been constructed and the effects of its location may extend over a long number of years. Thus adequate planning before the site is chosen may possibly prevent greater problems to the environment in the future.

Nature of Project

With the increasing number of stabilization ponds, it becomes desirable that they be located where they will least affect the present and future uses of water, cause the least amount of nuisances, and be economical with respect to location and construction. These desirable characteristics cannot always be fulfilled and thus a compromise must be made when choosing the site of the pond.

At present there is no conventional method for evaluating various site characteristics and construction practices of areas or sites where wastes are released to the ground. Studies have been conducted on various phases or areas relating to stabilization ponds including the theory of treatment, and the degree of treatment. From various earlier studies of stabilization ponds, suggested design criteria have been developed. Previous site selection has in a large number of cases been limited by economical considerations or the lack of detailed study by the designer. Partially because of the limited site evaluation, problems have occurred. The problems have ranged from odors and mosquito nuisance to land and water problems.

The satisfactory operation of the ponds are dependent upon various site and construction factors. The final design may be less than desirable because of the time needed for study of the influencing factors, the random nature of these factors, and the general nature of some of the design criteria. The preliminary evaluation is probably the most important aspect of stabilization pond design and usage. Once the pond is in operation, the only solution for many of the problems may be expansion or relocation.

The objectives of this project were:

a) to evaluate the overall influence of stabilization ponds on the surrounding environment,

b) to evaluate site conditions (location, soil, etc.) of various ponds in relation to their operation and acceptance,

c) to evaluate special construction practices which will assist in overcoming problems caused by site selection, and

d) to develop a method for rapid, economical site selection and to suggest construction practices for this pond location.

Scope of Data

Design data in the past has been largely extrapolated from existing ponds which appeared to be in good operation. Because stabilization ponds were used almost exclusively as a treatment unit for domestic wastes, design criteria has largely been for this type of waste. It appears that in the future the number of ponds used for treating other wastes will greatly increase.

Because of the vast number of ponds in operation, limitations were necessarily placed on the number of ponds evaluated in this study. Although compared to the total usage of ponds this appears to be a somewhat limited area, the data and results can be extrapolated to other areas or they may at least provide a reasonable start for developing a method of preliminary site evaluation.

The data for this project were gathered in two phases. First a questionnaire was sent to all stabilization pond operators listed by the South Dakota State Department of Health, and, second, personal visitation was made to a number of ponds during the summer of 1966 and the first part of June, 1967.

The returns obtained from the questionnaire represent a cross-section sample of stabilization ponds. A listing of communities returning the questionnaires are given in Appendix A. A map with the location of the existing stabilization ponds indicating those that replied to the questionnaire, and those that were actually visited is shown in Figure 1. The returned questionnaires included replies from two of the largest ponds, Watertown and Belle Fouche, as

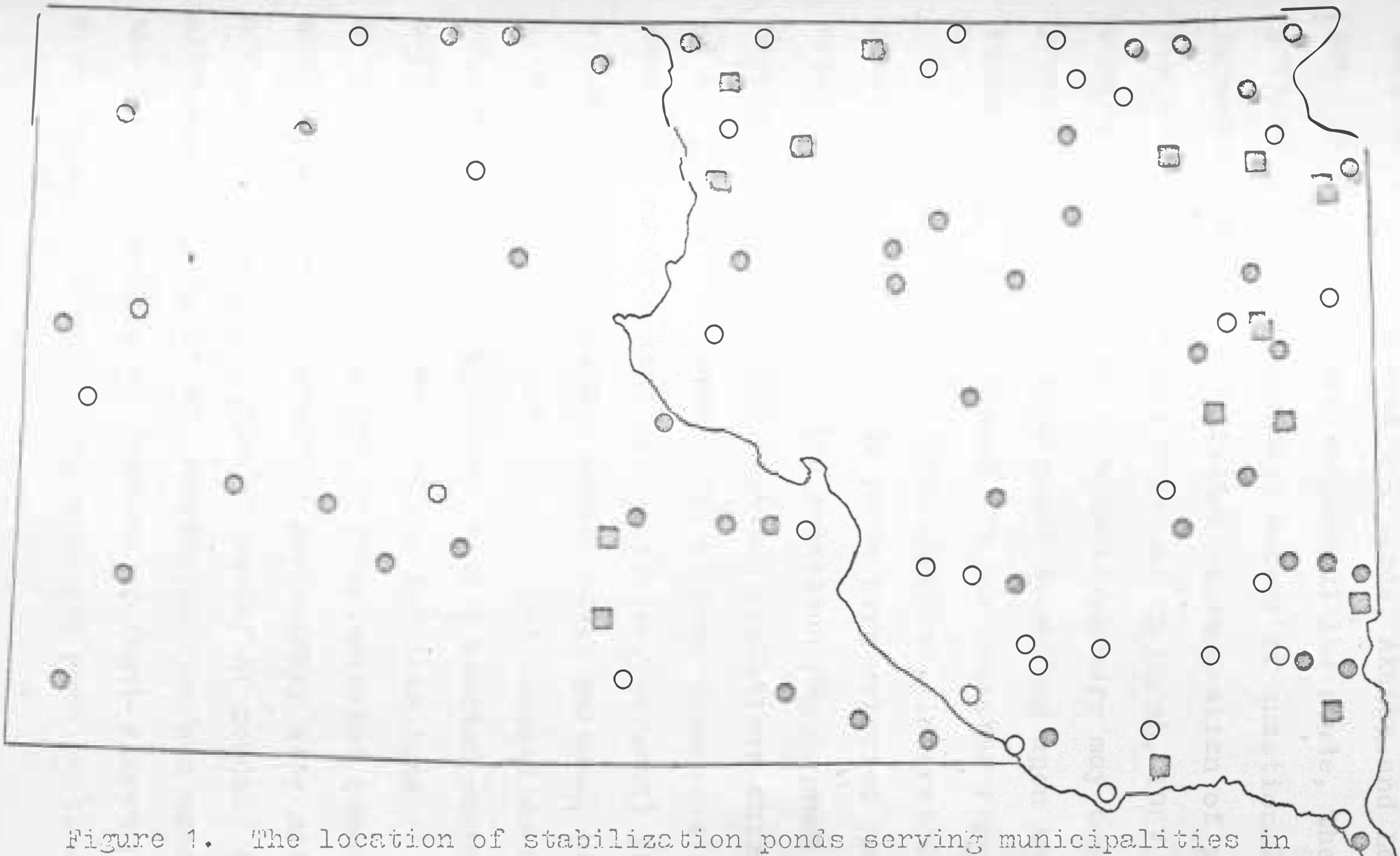

Figure 1. The location of stabilization ponds serving municipalities in South Dakota designating those evaluated in this study. (The darkened circles (○) represent ponds for which questionnaires were returned, and the darkened squares (□) represent ponds for which questionnaire and site visit information was obtained.

well as two of the smallest ponds, Akaska and Long Lake. The ponds were located throughout the state, the eastern portion having the greatest number of questionnaires returned because of the greater concentration of ponds. The questionnaires were sent out in March, 1967. The observations reported in a questionnaire may cover a period up to ten or more years depending upon the construction date of the pond and the operator reporting.

From the returned questionnaires, interviews and previous studies, various ponds were selected for visitation. The basis for the selection was dependent upon seepage, sealant, and/or special conditions which existed at the ponds. The data obtained from these visitations were from records kept by the cities, personal interviews with the operators and/or other persons, and actual examination of the site itself. The inspection of each pond was of a general nature with a limited amount of detail gathered. The two reasons for this type of investigation were: (a) to duplicate anticipated economic field studies which would occur in preliminary site selections, and (b) to observe a greater number of ponds. A considerable portion of the visitation time was spent with the pond operators, who because of their direct contact with the pond were familiar with the pond problems and could contribute suggestions for the successful operation and design of a stabilization pond.

LITERATURE REVIEW

Brief History of Stabilization Ponds

Although the use of soil for waste disposal is as old as the need for disposal, it is also one of the newer and more promising methods of sewage treatment (1). Early biblical history records the sanitary codes that were deemed necessary for the protection of public health (2-7). It was reported (1) that the first irrigation project designed primarily to treat sewage was in Bunslau, Prussia, in 1559. The first Royal Commission of Sewage Disposal of England in 1857 recommended continuous application to land as the proper method of disposal to avoid pollution of rivers.

In the United States, soil disposal has undergone cycles of popularity from extensive use of sewage farms in the late 1800's, diminishing in the 1900's, until an extensive reuse was started by the advent of the stabilization ponds in the 1930's (1). The development of stabilization ponds resulted from the practice of land disposal of sewage effluent for irrigation water. The use of ponding was developed almost simultaneously in the Midwest, Southwest, and California during the early 1900's. In 1901 the City of San Antonio, Texas, constructed a holding pond of 680 acres, averaging 4 to 5 feet in depth, to permit more efficient use of water for irrigation. Algae appeared and oxidation of the sewage occurred (3). In 1924, Santa Rosa, California, discharged the city sewage to an exposed gravel bed, expecting that the gravel formation would act as a natural filter. The beds soon sealed and filled to a depth of about three feet. The overflowing effluent was found to resemble the effluent from a trickling filter (4). Similar experiences occurred at other sites such as Vacaville, California; Fessenden, North Dakota; and in Texas (2-15).

Prior to 1948, there had been little or no recognition on the part of any official agency that a raw sewage lagoon was an acceptable method of handling wastes, although pond treatment was accepted for primary treated effluent (4). No engineering designs appear to have been made for a pond to handle raw sewage on a permanent basis, although various cities were using ponds for raw sewage treatment. Svore reported (4) that Texas had some 200 installations of this type at the time.

Maddock, North Dakota, is generally credited with having the first modern-day stabilization pond designed for the treatment of raw sewage. Although this pond may have been designed on an experimental basis, the design established many of the criteria used in present day pond design. The pond had an area equivalent to 1 acre per 100 population and a maximum depth of 5 feet. Two additional ponds were added later because the seepage and evaporation were insufficient to handle the flow (4). The second and third ponds provided some additional treatment, however, the basic treatment occurred in the first pond. Favorable results at the Maddock pond led to their wider use in North Dakota until in 1960 approximately two-thirds of the sewered municipalities in the entire state had stabilization ponds (4). With continued success of the municipal ponds, other states began using stabilization ponds for the disposal of raw wastes. The first stabilization pond in South Dakota was put into operation in 1951 at Lemmon. To date, ponds are being used by over 100 South Dakota communities to treat raw sewage or for additional treatment following conventional wastewater treatment plants (5). Similar installations can be found for most other Midwestern and Western states.

As the numbers of stabilization ponds were increasing for domestic waste treatment use, industrial applications of ponds were also experiencing a rapid growth. Pond use for the lagooning of industrial wastes had been employed prior to its application for treatment of domestic sewage, however, stabilization or treatment of the wastes was not the primary objective. The ponds were used as seepage pits, settling basins, or for storage until greater dilution was available in the receiving streams (6) (7). The total number of industrial ponds is difficult to obtain. Various reports (8) (9) give indications of extensive use of stabilization ponds for industrial wastes, however, little data are available on the total number of these ponds. An example of the number of ponds was shown by a survey of waste treatment methods in six Midwestern states revealing that of 365 canning plants, 168 or 44% used lagooning for waste treatment (10). Stabilization pond uses were reported (8) for most types of industry, the majority being used by the canning, meat, chemical, paper, and petroleum industries.

A possible significant use of stabilization ponds is for farm waste treatment. Curtis (11) reported that the disposal of these wastes through the use of lagooning is becoming more popular in the Midwest. Because of the limited reporting and data, the total number of farm ponds is difficult to determine. Porges cited an article which indicated that there were over 200 ponds for the treatment of hog wastes in Missouri alone (8).

Stabilization Pond Design

Although the design of stabilization ponds is relatively simple, a basic understanding of the biological and chemical processes is essential (12). The process involved in satisfactory operation of a stabilization pond is a complex biological-chemical relationship between algae and bacteria (13-1). The pond first acts as a dilution and settling basin in that incoming wastes are diluted and suspended solids soon settle to the bottom (5). The bacteria digest and oxidize the waste materials releasing carbon dioxide and ammonia, which in turn are utilized by the algae. The algae require these materials for their photosynthetic action which in turn makes oxygen available for the aerobic bacteria. The mechanisms of the stabilization process are shown schematically in Figure 2.

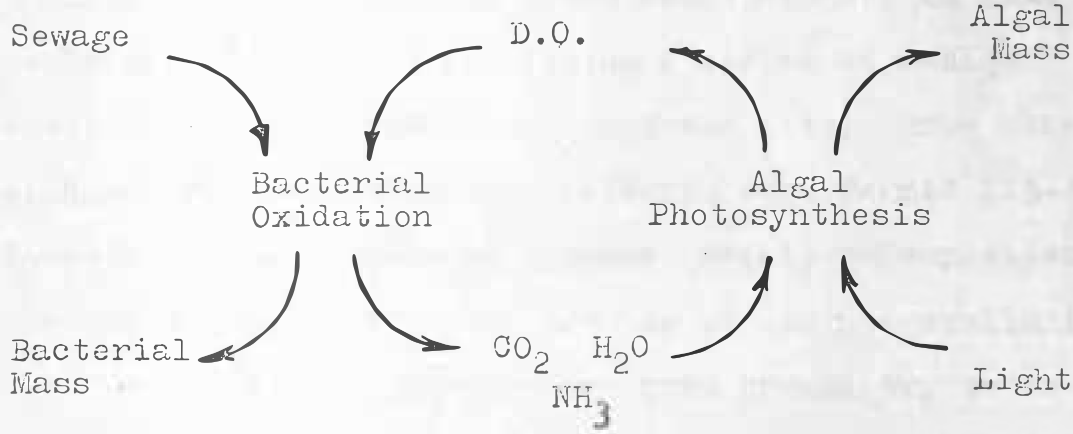

Figure 2. Stabilization Mechanism (13-13)

Algal activity is almost negligible under snow-covered ice; stabilization that is accomplished during the winter months in colder climates is primarily a result of physical forces and anaerobic bacterial activity (13-1). Odors normally occur during the winter to spring transitions (5). Although the theory of treatment is relatively simple, each individual characteristic must be present for the successful operation of this type of pond. Thus in designing a stabilization pond, factors which will insure these characteristics must be incorporated.

Because of the lack of data and research, the United States Public Health Service and the North and South Dakota Departments of Health in 1955 and 1956 undertook a study of the design and operational effects of five ponds in the area (5) and set up a series of design standards for the practicing engineer (14). From these studies, recommended design criteria were formed (13-4). To date, criteria have been based largely on experience drawn from the observation and use of early installations.

The basic design considerations should try to incorporate as many of the following objectives as possible: (a) economics, (b) satisfactory treatment of the waste, (c) prevention of nuisance conditions, and (d) prevention of pollution of the surrounding environment. The relative weight of each of the above factors must be determined for each specific case and the design adapted to obtain the desired results. In January, 1960, a Committee of the Missouri Basin Engineering Health Council reported on a study to document the design, construction, and operation practices normally used for waste stabilization lagoons. The report (15) concluded that because stabilization ponds were successfully adapted to extremely varying conditions, strict design criteria were undesirable. The report left each state wide latitude as to specific practices to be recommended for that state. While the early studies did not develop mathematical design formulas, they did point out general design factors that required consideration. It was demonstrated that properly designed and operated stabilization ponds would provide a comparable degree of purification, but that like any other method of treatment, they are subject to disadvantages (6).

Need for Site Evaluation

Because of the wide variation in conditions of design, most writers point out the need for preliminary site study prior to pond design. Towne (6) stated,

> Although stabilization ponds appear to be simple in their design and operation, it is essential that they be designed by people having a thorough knowledge of the factors contributing to their success and/or failure. The design criteria may vary radically between different climatic and geographic areas and for these reasons the designing engineer should not attempt to blindly apply such criteria without considering the local factors involved.

Other sources (5)(12)(16) agree that an economic and engineering study and evaluation of local conditions similar to that necessary to locate any type of waste treatment plant are necessary and the most practical approach. Culp (12) states, "In designing waste stabilization ponds, site selection is a critical feature."

However, even though the importance of preliminary studies are widely accepted, the actual design of ponds does not always follow the accepted thinking. Filipi (17) stated that because stabilization ponds appear to be a very simple structure, engineers do not give sufficient attention to preliminary studies and make assumptions on too many details. In observing ponds in Nebraska, he stated that problems are caused by (a) inadequate preliminary study, (b) inadequate and improper design, (c) faulty construction, and (d) lack of operation. A close examination of conditions and problems suggest that what is known regarding soil disposal is not always applied or even applied in the correct manner (1).

Problems Associated with Stabilization Ponds

The increasing use of stabilization ponds has also caused various problems. Problems may be classed as treatment problems, nuisance problems, and contamination problems. These may be present as separate problems or may be interdependent. Often the problems are associated directly to some design feature of the pond (17).

The major complaints about stabilization ponds by the public normally pertains to odors and/or nuisance conditions such as mosquitoes near the pond. Odors are attributed to three factors: the normal odor caused by spring overturn, improper design and operation, and overloading (5). Most recommended criteria try to eliminate the odor problems by locating the ponds as far from communities and habitation as is reasonable and practical. However, it is felt that ponds operating satisfactorily give no more odors than a satisfactorily operating conventional plant and therefore can be located at a comparable distance (12). Where transition problems are extensive, VanHeuvelen (18) stated that odor problems would probably have existed with a conventional treatment plant. Odors also appear to be related to the sulfate content of the local water (16)(18)(19). Although several materials have been applied to stabilization ponds to control odors, sodium nitrate appears to be the only compound to give consistant results (10).

A second area of public complaint is the insect nuisance problem, especially with mosquitoes. Because the mosquito is not only a nuisance, but also a vector of encephalitis, control of production becomes important from a public health aspect. A study (20) published in 1960 presented evidence that stabilization ponds are producing mosquitoes of sufficient numbers to be significant. It was found that mosquito production was directly proportional to the extent of vegetation in the ponds, and thus related to the pond operation. Again it appears that location at a sufficient distance from the community and habitance will partially solve the problem (17) as will properly engineered and operated ponds (3).

Possibly the greatest problem caused by stabilization ponds is the contamination of the land, surface water, and ground water. Because of the direct contact with the land, some land contamination must be assumed. However, the greatest threat from stabilization ponds is probably the problem of groundwater contamination. Considering the increasing uses of the groundwater plus the nature of its movement, contamination becomes notonly a serious problem today but possibly even a greater problem to the users in the future. Recognition of the importance of safeguarding the water supplies and consideration of potential hazards were made in the early pond studies (2-45). However, a study of five Southwest states showed requirements by most states concerning the proximity of the ponds to habitation, but requirements for location with regard to proximity of surface and groundwater supplies was rather diversified (3). The South Dakota design criteria (5) for stabilization ponds states that the proximity of ponds to water supplies and other facilities subject to contamination should be critically evaluated to avoid creation of health hazards or other undesirable conditions.

The major cause of groundwater contamination from stabilization ponds is seepage. In 1955, a preliminary study (14) was made at Hope, North Dakota, where surface evidence indicated that liquid from the pond was infiltrating the soil at a rate approximately equal to that of the influent to the pond. The study was expanded to include the five ponds which were being investigated by the North and South Dakota Health Departments (13). Test holes were dug and the analysis of the liquid samples indicated that the seepage liquid was from the ponds and that the ions content decreased with distance from the pond. During the study seepage was found at all but the Maddock, North Dakota ponds.

One reported case (21) of seepage at Tieton, Washington, ended in a court decision in 1959 against the city for contamination of the groundwater. The criteria employed were for the most part unknown, but several significant conditions such as soil factors and flow factors seemed to have been neglected in the design. In 1960, it was reported that Nebraska had four ponds that were completely dry (17).

Preliminary studies in the summer of 1966 (22) indicated that seepage occurred from some ponds in South Dakota. Matthew (19) reported in 1966 that the inability to maintain adequate water depths has resulted in the partial or total failure of from fifteen to twenty units in South Dakota and is considered to be a major design problem in many other states. In addition, he reported that under severe water loss conditions, the unit does not serve as a wastewater treatment facility; public health problems develop; groundwaters may be contaminated; and nuisance conditions occur.

Not only do stabilization ponds for domestic sewage pose a threat to the groundwater, but the increasing number of ponds which are being used for industrial and farm waste may present an even greater danger. This may occur because of the high loadings, the large number of ponds, and/or the chance of introducing some exotic element which is only safe at low concentrations in the groundwater. Concerning farm ponds Curtis (11) stated,

> There are situations known where lagoons have been constructed in porous soils or have been grossly overloaded due to underdesign. It is certainly safe to say that in the case of lagoons, there is constant gross contamination of the groundwater because of the very characteristics of the material placed in the lagoon.

Despite the relatively long history of land use for waste disposal and treatment, relatively little is known of the potential and limitation of stabilization ponds concerning groundwater pollution (1) and the effects upon the environment. Because of the number of variables, early and precise predictions of the effects of the pond on the groundwater are almost impossible (23). A pond, once constructed, is a relatively permanent installation. If problems exist, in many cases the only solution will be relocation. This points out the importance of preliminary site selection.

Travel of Pollutants

It has been found that distance from the community and habitation reduces most problems caused by various pollutants from stabilization ponds. One of the two major disadvantages of stabilization ponds is the necessity of finding a site that is well located to prevent the creation of nuisance or problems should they develop (10). Distance has already been mentioned as a means for the reduction of odor and insect problems. Although factors related to distance reduce most of the pollutants of the land and groundwater, study and prediction of this influence is extremely more complicated than in the case of odors or insect problems. Various contaminants differ greatly in their subsurface behavior. Many of them decay or are sorbed on earth materials, and almost all contaminants lose some of their potency by dilution in the groundwater (23).

Research (1)(24) has shown that removal of contaminants by soil systems varies with conditions of soil, loading, area, and depth. Research seems to be lacking in the hydrogeologic area specifically for stabilization ponds, and thus prediction of travel of pollutants must rely on studies made in other areas. In research conducted for sewage reclamation at a California site (25-161), and at a South Dakota sanitary landfill (26), it was found that although these sites had influenced the chemical quality of the groundwater, after passing through soil for an appropriate distance the overall quality change was insignificant. In the California study (25-161) this distance was approximately one-half mile from the site. Bacterial reduction was very rapid, and under most circumstances the bacteria did not penetrate further than 100 feet. Another study concluded that bacterial contamination normally would not be a factor of concern in sewage reclamation (27-182). Butler (14) found that ion concentration decreased with distance from the stabilization pond and stated that, in general, chemicals can be expected to

(16) reported limited use of bentonite and asphaltic sealants in South Dakota. Experience with bentonite in extremely sandy soil proved to be unsatisfactory (16). The pond sealed with asphalt was found to exhibit seepage in 1966 (22-20); however, another pond had been successfully sealed with clay (22-23).

The sodium content of water is of interest because excess sodium makes soil less permeable, and may tend to help seal the pond bottom (13-54). In one instance where salt was used for sealing a pond (29), it was reported that the sodium ion in the salt water replaced the calcium ion in a clay soil. The sodium clay became sticky, deflocculated and became impervious to water. The quality of water in the pond was not affected by the salt water treatment of the lining.

It appears essential that steps must be taken to protect groundwater resources from chemical contamination rather than to attempt corrective measures after the contamination has occurred (30). Without precise and simple methods to evaluate sites, reliance must be placed on certain arbitrary standards that attempt to weigh the probability of contamination with the seriousness of consequences of such contamination (23). A need exists to define the acceptable limits of contamination at an early stage of planning (31).

FACTORS WHICH INFLUENCE SITE SELECTION

The location of a stabilization pond is dependent upon several physical factors. These factors are important to the four basic reasons for selection of sites: the protection of the surrounding environment, the prevention of nuisances, the satisfactory treatment of the waste, and the cost of construction and operation. The physical factors of major concern for site selection are interrelated, therefore, optimum site selection cannot be made by only considering a single factor.

Nature of Waste

The characteristics of the waste, both quality and quantity, partially determines the requirement for treatment, the possibility of nuisance, and the change in the nature of the surrounding land and groundwater. Wastes range from highly toxic wastes to relatively pure cooling water and storm runoff.

Various recommendations have been made with regard to the loading of stabilization ponds and are mostly concerned with the local climatic conditions. Special limitations such as high sulfate content of the water also restrict the pond loadings. Ponds are normally designed on a basis of population equivalents. Thus, in South Dakota a community treating domestic wastes only would design for 1 acre/100 capita (5). If an industrial waste is also placed in the pond, additional area is required relative to the strength of waste when compared to domestic sewage. This, however, may cause problems with hydraulic loading. Certain industries may contribute significantly more or less water volume than domestic sewage for equivalent organic loadings. This may cause low or high water levels in the pond. Matthew (19) recommended that the hydraulic application rate be considered in stabilization pond design and that consideration be given to increasing the allowable organic loadings for concentrated wastes. The application of present standards often result in low hydraulic loadings which cannot realistically be expected to maintain adequate water depths.

Because there is a wide variety of wastes which are composed of different chemical and biological constituents, each waste must be analyzed. These wastes may include agricultural, domestic, and industrial wastes. Certain chemicals may contaminate the groundwater or be toxic to the pond growth. Thus, the problem becomes one of predicting what will be the critical contaminants and at what concentrations will they be of importance.

Distance and Direction Considerations

The distance that a pond should be located from the community is dependent upon two opposing considerations.

First, the pond should be ideally located near the town to keep the length of the outfall sewer to a minimum and possibly to eliminate the need for a lift station. Conversely, maximum distance is desirable in order to keep odors, mosquitoes, or groundwater contamination problems to a minimum. The South Dakota recommendations (5) state that, "A site should be as far as practicable from habitation or any area which may be built up within a reasonable future period."

Most states have requirements concerning the proximity of ponds to habitation. Although variation does occur, the recommended distance is approximately from 1/8 to 1/4 mile from nearby habitation and 1/4 to 1/2 mile from the community. Consideration should be given to the direction of possible community growth and the future use of the surrounding land.

Prevailing winds are an important consideration in determining the distance and direction of the pond location from habitation. An unobstructed wind sweep across the ponds is desirable for mixing and reaeration; however, prevailing winds should be in the direction of uninhabited areas. When designing a pond, the seasonal direction of the wind should be considered. For colder climates, consideration should be given to pond location in order to minimize problems caused by expected odors that may occur during the spring transition. The design wind direction may therefore differ from the annual average.

For South Dakota during the spring transition in March and April, the prevailing winds were found (32) to be from the southeast and northwest a majority of the time. An overall study of wind conditions during the spring and summer shows that the prevailing winds are predominately from the south and southeast; however, northwest wind directions are significant. Therefore, for South Dakota, the location of the pond would ideally be southwest or northeast of a community.

Soil Conditions

The condition of the soil is probably the most important factor which influences site selection, but one of the most difficult factors to evaluate. The water retention properties of the pond, the rate of water movement though the soil, and the partial removal of contaminants as the water percolates are affected by the nature of the soil. Although many aspects of soil properties are complete studies in themselves, sorption and permeability are of greatest concern.

Sorption is the retention of a contaminate on a soil material. It has been related to soil particle size, but the effect of size on the influence of the sorptive properties is not fully known. Clays and silts tend to have a greater sorptive capacity than sands. Although different clays may have widely varying degrees of sorptive capacities, no distinction will be made in this study. Also it would be expected that each type of contaminant would have different sorptive characteristics in different soils.

Permeability is a measure of the ability of soil to allow water to move through it. Movement of water occurs through pores separating mineral grains in soils or through linear openings in consolidated rock. Great variations in the degree of permeability are found in the same area. Permeability is an extremely complicated factor and is dependent upon a large number of variables. Contrasts of permeability are especially apparent in a vertical direction where different sedimentary layers have been deposited. Changes in permeabilities of different soils can be a significant factor in the travel of contaminants. It is generally agreed that soils with larger particle sizes have greater permeabilities. For instance, clays have a small particle size and a correspondingly low permeability.

The ability of a pond to hold water is related to permeability. Matthew (19) conducted several standard tests to determine the engineering characteristics of soils collected from various pond sites. He concluded that none of the tests proved to be a suitable indicator for evaluating percolation losses. The permeability test, coupled with subsurface investigations, appeared to be the best method available for predicting the potential for these losses. Recognizing the various shortcomings of the available testing procedures, it is generally concluded that clays have good water retention properties and gravels do not.

A pamphlet (33) published by the Soil Conservation Service of the United States Department of Agriculture summarizes soil limitations for stabilization ponds as shown in Table 1. In regard to Table 1, it was stated:

> Permeability of soil material at reservoir site-- Soils classified in the unified soil classification system are grouped into three classes according to their "degree of limitation" for a sewage lagoon site. The "slight" limitation class includessoils effective in functioning as sealed basin floors and are low in organic matter. Soils in the "moderate" limitation class are those that require special practices or treatment to modify soil limitations so they qualify for use as sewage lagoons. Soils placed in the "severe" limitation class are those that are either very porous or high in organic matter or have other limitations that prevent their use for sewage lagoons.

Water Table Conditions

With the increasing use of the groundwater plus the nature of its movement, an important factor dealing with stabilization pond design is the protection of groundwater resources. The water table conditions, unlike the soil conditions, may fluctuate greatly over a period of

TABLE 1

Soil Limitation Classes for Lagoons (33)

Soil Properties	Limitation Class		
	Slight	Moderate	Severe
Permeability	Less than 0.60 inch/hr	0.63 to 2.0 inch/hr	Over 2.0 inch/hr
Depth to bedrock	Over 60"	40 to 60"	Less than 60"
Slope	Less than 2%	2 to 7%	Over 7%
Reservoir site material (Unified grouping) *	GC, SC, CL, and CH	GM, ML, SM and MH	GP, SW, SP, OL, and OH
Coarse fragments, under 6" in diameter, by volume	Less than 20%	20 to 50%	Over 50%
Percent of surface area covered by coarse fragments over 6" diameter	Less than 3%	3 to 15%	Over 15%
Organic matter	Less than 2%	2 to 15%	Over 15%

*Refer to reference for description of groupings time; however, these basic factors are relatively easy to determine at any specific time. Water table conditions of importance include: water table depth, distance to point of withdrawal, and water table gradient.

Depth to the water table fluctuates greatly throughout the year. The water table level tends to be more stable in areas with low permeabilities. The higher the groundwater table, the greater the contamination potential because of the lesser distance that the contaminate has to move to enter the aquifer. In extreme cases where the water table level is very near the ground surface, direct seepage into the aquifer is probable.

In order for damage to result from the presence of contaminants, they must move to some point of withdrawal where the water is used. The greater the movement distance, the less the chance of damage. This can be the result of the dilutional effects of the groundwater, dispersion in the groundwater, and removal of contamination by soil sorption. The hydraulic gradient should be evaluated to determine if the flow of contaminated water is moving towards or away from a point of withdrawal.

Uses of the Surrounding Environment

The use of the surrounding land and the uses of the groundwater are important factors in selecting a pond location. Generally direct land pollution by stabilization ponds is not significant. If the potential site is located near land of high value and extensive usage, economic and aesthetic considerations would probably exclude it as a stabilization pond site.

Uses of the groundwater may vary quite significantly and require different degrees of groundwater protection. Bacterial contamination will not normally be a critical factor unless the point of withdrawal is immediately adjacent to the pond. Chemical contamination may dictate the uses for which the groundwater is suited or the degree of water treatment required. The various uses will depend upon the quality of the groundwater and will establish the level of constituents that may be tolerated in the water. For example, a water with a high sodium concentration would probably be rejected as an irrigation source while it may be satisfactory for use as a domestic supply. If more than one use is made of the water, such as for individual domestic supplies and irrigation, the critical factors for both uses must be evaluated.

Gravity Flow

The use of gravity sewers to convey the waste to the stabilization pond is not only less costly but also presents fewer operational problems than pumping. Even though gravity flow does not affect treatment or pond characteristics, this factor must be considered in site selection because of its economic advantages.

Depth

The ability to maintain an adequate water level is one of the most important aspects for a successful stabilization pond. The satisfactory operation of a pond is dependent upon a range of liquid operational levels. For operation as an aerobic pond, the depth of the liquid is generally limited to about five feet. At greater depths the pond lacks good mixing characteristics and may become anaerobic. It has been found that a minimum depth of three feet is generally sufficient to discourage the growth of rooted aquatic plants, and at the same time, this depth provides sufficient volume for treatment and storage. The South Dakota State Health Department (5) has set the following operating limits: minimum depth of two feet and maximum depth of five feet.

It appears that variation in pond depth throughout the season may be desirable. For example, the pond level could be drawn down in the spring when the volume of dilution water in a receiving stream is greatest. During the later spring and early summer the pond would be allowed to fill which would discourage weed growth. In the fall the pond level would again be lowered to permit storage during the winter when the pond is operating at the lower efficiency under anaerobic conditions.

Water Balance and Seepage Loss

Inadequate water depths have been the greatest cause of pond malfunctions. A basic water balance can be applied to stabilization ponds to determine if adequate depths may be maintained. The terms that must be included in a water balance are shown by the following equation.

Influent + Precipitation + Surface and Ground-water Inflow = Evaporation + Transpiration + Overflow + Seepage + Change in Storage

Flow of domestic sewage to ponds may vary between 20 and 100 gallons per capita per day (gpcpd), and depends upon the water availability, the age of the sewer, the number of house connections, and other miscellaneous factors. Measurements of sewage flow into ponds are not normally made; however, these flows can be estimated. Matthew (19) stated that the per capita design flow of 100 gpcpd for small rural communities without industrial or commercial waste is unrealistic. He considered application rates ranging from 40 to 65 gpcpd as more realistic.

Estimates of wastewater volume can be obtained from water usage. Clark and Viessman (34-41) report that the domestic sewage flow is approximately 0.6 to 0.7 of the water usage. From the water records of six South Dakota communities studied during this investigation, it was found that the average water usage was 76 gpcpd. Applying a factor of 0.7 as suggested by Clark and Viessman, the average domestic sewage flow would be about 53 gpcpd. This volume is in agreement with those reported by Matthew.

Part of the water volume in a pond will evaporate; however, precipitation will also fall into the pond. The amount of evaporation and precipitation will vary from location to location. Meyer (35-58) reported that the mean annual evaporation exceeds the mean annual precipitation in South Dakota by 15 to 30 inches per year.

An example of the volume of seepage loss can be calculated. Using a 1-acre pond as the basic unit, an average waste flow of 50 gpcpd, and the present design recommendation of South Dakota (1 acre/100 population), a hydraulic application rate could be calculated as:

$$100 \text{ population} \times 50 \text{ gal/day} \times 365 \text{ days} =$$
$$1{,}825{,}000 \text{ gal/year} = 1.825 \text{ MG/yr}$$

The volume lost by evaporation using 20 inches/yr of excess evaporation over precipitation gives:

$$20/12 \text{ ft} \times 1 \text{ acre} \times 0.3259 \text{ MG/acre-ft} = 0.543 \text{ MG/yr}$$

Thus, if the pond does not overflow and the storage remains the same, approximately 1.3 million gallons per acre per year or 67% of the total liquid volume is seeping to the land or groundwater.

Consideration should be given to the nature and concentration of the contaminants escaping the pond by seepage, and their influence on the groundwater quality. Preliminary data (22-25) for the Volga and Milbank ponds has shown that the seepage water contained significant amounts of contaminants. Analyses of grab samples taken from the vicinity of the ponds indicated that the chemical quality of the seepage water was nearly identical to that within the pond. Because of these analyses and large volume of seepage from the ponds, it appears safe to assume that at least some of the contaminants are influencing the nearby groundwater.

Other Pond Applications

Although the data from this project were limited to municipal ponds, the basic purpose of the study can also be incorporated into the other areas in which stabilization ponds are used. Two types of ponds will be briefly discussed.

Farm lagoons have been proposed for the efficient disposal of animal wastes resulting from the large scale feeding operations which have developed in the past few years. The utilization of this type of a pond has not been fully developed; however, the potential for adapting this type of treatment seems unlimited because of the availability of land. At present it appears that farm ponds are the only feasible method available for the treatment of these wastes. However, from an economic and environmental viewpoint, it has yet to be shown that these ponds can be satisfactorily used for treatment.

The location of farm ponds would normally be upon the owner's land. Here, of course, acceptance of such factors as odors and nuisance would principally be of concern to only the owner and tenant. The problems of water and soil pollution, satisfactory operation, etc. would still exist. Because of the simplicity of farm pond construction, detailed engineering studies are not normally utilized in regard to pond design and location.

The utilization of stabilization ponds for treating industrial wastes is not new, but the use of these ponds as a treatment device is receiving increased attention. Industrial wastes are of such a varied nature that conventional waste treatment methods are often costly and may not give satisfactory treatment. Stabilization ponds have the advantage that they can receive shock loadings or erratic flows which are typical of industrial operation.

Because of the varied nature of the wastes and the objectives of the desired treatment, each type of waste must be analyzed as to the waste characteristics and hydraulic loadings. Site selection is especially important because of the nature of the wastes involved. Industry in contrast to the farms are normally located near populated areas where nuisance and odors, as well as contamination must be controlled. In these instances more detailed investigation should be given to pond location.

QUESTIONNAIRE RESULTS

In the spring of 1967, a questionnaire pertaining to various site characteristics was sent to the operators of all of the 96 known stabilization ponds in South Dakota. A copy of this questionnaire may be found in Appendix B. A total number of 64 questionnaires were returned. The results of this questionnaire are summarized in Appendix C.

The returned questionnaires were corrected after actual observations were made at various sites or other data indicated that the returns were erroneous. The total number of corrections was relatively small. Personal observation of a number of ponds indicated, in general, excellent agreement with the returned questionnaires. For certain questions more than one answer was possible. Some questions were not answered by all the operators and thus the number of replies to specific questions did not always total the number of returned questionnaires.

Depth

It has been previously stated that the recommended operating depth of a stabilization pond is between three and five feet, and that the South Dakota Health Department has placed the minimum operating depth at two feet and a maximum depth of five feet. Results of the questionnaire showed that 10 of the 64 ponds were operating at depths of less than the minimum of two feet. The questionnaire also revealed that nine of the ponds were operating between the standard minimum depth of two feet and the recommended minimum depth of three feet. Eight of the ponds were operating at a depth over the recommended five feet. Thus 37 of the reported ponds were operating between the recommended levels. Table 2 shows the percentages of ponds operating at various depths as determined from the questionnaire.

TABLE 2

Operating Depth Distribution, Weed Problems, and Obvious Seepage of Ponds Surveyed by Questionnaires

Depth Range	Ponds (no.)	Ponds (%)	Ponds with Weeds (no.)	Ponds with Obvious Seepage (no.)
Under 2 feet	10	15.6	8	8
2 to 3 feet	9	14.1	2	5
3 to 5 feet	37	57.8	3	18
Over 5 feet	8	12.5	0	1

Table 2 reveals that 15.6% of the ponds surveyed by the questionnaire are possibly exhibiting seepage or have low hydraulic application rates because satisfactory depths are not being maintained. In addition, those ponds operating at the 2 to 3 foot depths may be exhibiting the same conditions. It should be noted that in ponds having weed growth, some transpiration losses would occur.

An interesting comparison of operating depth with weed growth was noted. Of 10 ponds operating at less than 2 feet, 8 reported problems with weeds. This would be expected. However, two ponds of the nine installations at an operational depth between two and three feet reported weed growth. It is possible that there were areas in these ponds that had depths of less than two feet. Also it was found that 3 of the 37 ponds operating within the recommended limits had weed problems.

The data are representative of single-celled ponds and multiple-celled ponds operating at the same liquid depths. However, in certain multiple-celled ponds, the water depths varies between cells within the installation. In the tabulation of results the greatest operating depths indicated were used, and thus the extent of seepage as shown by depth considerations isnot completely represented. Most multiple-celled ponds were found to operate in series. When depth variation occurred, the greatest liquid depth was in the primary pond.

Depth Fluctuation

It was reported that in the majority of the ponds the depth did not fluctuate greatly throughout the year. From the data it was observed that 44 ponds or 68.6% varied 1 foot or less. Only three of the returned questionnaires indicated the use of controlled drawdown. Therefore, this probably indicates that the recommended operational procedures for drawdown are not part of actual pond operation.

Overflow

The results showed that 29 of the 64 installations overflowed, 12 ponds overflowed seasonally or temporarily, and 23 of the ponds did not overflow. The significance of non-overflowing ponds is that the water balance is maintained only by evaporation or seepage. Because evaporation losses in South Dakota will not exceed the influent flow, the water must seep into the ground or be retained in the pond. Thus it appears that at constant depth at least 54.7% of the ponds are leaking to some degree. The reason that ponds may overflow only part of the time may be attributed to varying evaporation rates, seepage losses, controlled discharges, storage, or low influent rates. During wet periods evaporation and seepage may not be sufficient and overflow occurs. However, overflowing ponds may still be experiencing water losses by seepage as shown by the water balance equation.

Distance to Town

The questionnaires indicated that the majority of the ponds (65.6% or 42 ponds) were located within one-half mile of the town. Twenty-three or 35.9% of the ponds were located within one-quarter mile of the town. The distance to the community as previously stated would ideally be as close as possible for economic considerations, yet should be at a sufficient distance to buffer odor and other nuisances. In general, it was found that the greater the distance the pond was from town, the less were the complaints.

Direction to Town

The factor of location with respect to the direction from town was stated as important from a prevailing wind consideration. The results of the questionnaire showed that ponds were oriented in all directions with respect to the towns, and these directions were evenly distributed. Thus it would appear that the recommendations (5) concerning prevailing winds, which are generally from the south and southeast, have not been followed.

Distance and Direction to Habitation

The results showed that the distance to the nearest habitation was within one-quarter mile from the pond 59.4% of the time, and all but 11 ponds were located within one-half mile of a habitation. Because of the proximity to farms in the area (especially in the eastern portion of the state) it appears that considerable distance from habitations, although desirable, is somewhat difficult to attain.

Again it was found that ponds were located in all directions from the nearest habitation. Because of the number of nearby farms, the control of the direction to habitation presents a greater problem than does the control of the direction to towns. Considering the population involved, the major consideration for pond design with respect to prevailing winds should be based on town location.

Direction that Ground Slopes in Area

The natural flow of pollutants is most frequently in the direction of the slope of the ground surface. The groundwater may contain pollutants from a pond and therefore, it is important that the groundwater flow coming from the pond be away from sources of domestic withdrawal. Because a detailed survey including test wells would be needed to exactly determine the direction of groundwater flow, an estimate of the direction of flow was made from the slope of the land. Results of the questionnaire show that in six cases the ground slopes directly toward the city and in six additional cases the sloping direction is within 45° of a direct line toward the city. It was found that the ground generally slopes toward the nearest private withdrawal in 13 cases. This questionnaire dealt only with the nearest habitation; however, other withdrawals may be affected, as would other uses in the surrounding vicinity, such as withdrawal for irrigation or stock watering.

Soil

The questionnaire indicated pond locations in areas of varied soil types. The most prevalent type of soil in which ponds were located was clay. The questionnaires indicated that 20 ponds were located in a clay soil, and that 16 additional ponds were located in clay combined with another general soil type. Sand and gumbo (a type of clay) alone and in combination with other general soil types were found to be the next most prevalent soil types.

The relationship of reported soil types to seepage problems is illustrated in Figure 3. The questionnaire showed that of the 8 ponds located in sand or gravel, 6 ponds had visually observed seepage (obvious seepage) while one additional pond apparently had seepage because it did not overflow (apparent seepage). Also of the 15 ponds which were located in soil combinations containing either sand or gravel, 9 ponds had obvious seepage while an additional 3 ponds did not overflow or exhibited apparent

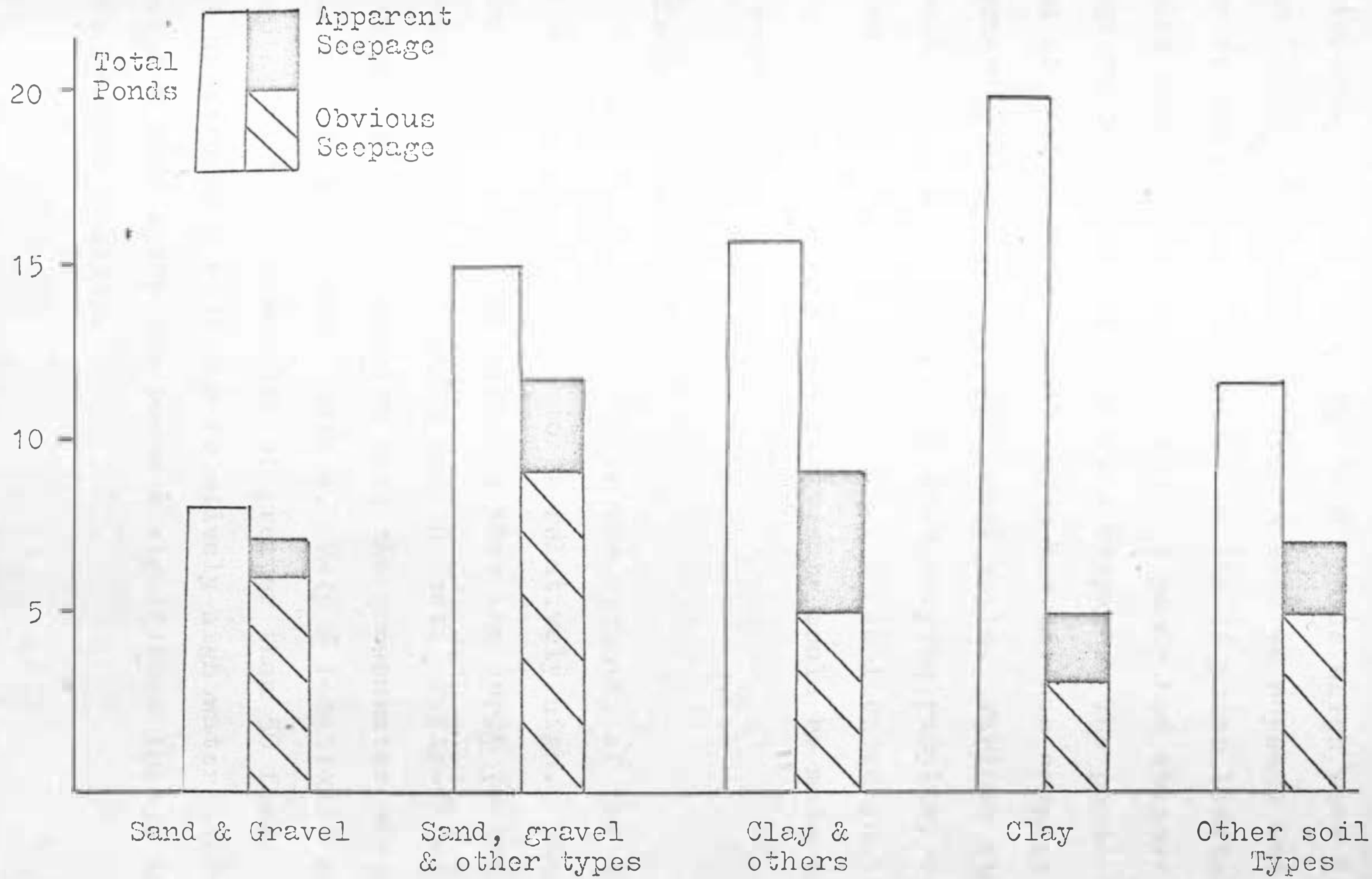

Figure 3. Comparison of soil types and seepage of South Dakota stabilization ponds based on questionnaire results.

seepage. In contrast, of the 20 ponds which were reported as located in clay, 3 ponds had obvious seepage and 2 ponds had apparent seepage. Of the 16 ponds located in clay plus another type of soil, 5 ponds had obvious seepage while 4 ponds had apparent seepage. The ponds located in clay plus another soil which had obvious seepage, in general, also had sand or gravel soils. Various other soils and soil combinations gave varying results, but because of the limited number of ponds located in these soil types no conclusive statements could be made concerning these soils.

Depth to Groundwater

The groundwater table in the vicinity of the stabilization ponds appeared to be relatively high. Twenty-two of the operators reported that the depth to the groundwater was between 0 and 10 feet. Fifty-three of the 64 operators reported that the groundwater was within 20 feet of the ground surface. Only 6 locations had depths to the groundwater of greater than 50 feet. Thus it appears that with the relatively high water table, seepage from the ponds poses a significant threat to the groundwater quality.

Other Flow to the Pond

A limited number of ponds received a significant volume of industrial wastes. The only industries of significance reported were from 18 communities that had small slaughtering or butchering plants, and 10 communities that had dairy plants which were discharging wastes to the ponds. Seven of the 10 ponds treating dairy wastes were reported to have odor problems, and 11 of the 18 ponds receiving slaughtering wastes reported odors.

Some problems were reported because of concentrated industrial waste, particulararily dairy waste. Ponds designed for the population equivalents of these wastes did not receive sufficient hydraulic loadings and thus organic overloading may have caused odors. In addition, at various ponds the wastes may have been concentrated because of seepage, and the problems would probably have been present anyway, although to a lesser degree.

Twenty-one of the questionnaires reported that additional drainage water was entering the ponds. This was a combination of direct land runoff and storm sewer influent to the pond. In several cases this drainage did not appear to have an adverse effect.

Obvious Seepage

Twenty-five of the 64 ponds or 39.1% experienced obvious seepage. It was reported that 8 additional ponds had obvious seepage to a limited extent. Comparisons between seepage and soil conditions has been previously made. Obvious seepage was probably observed as visual water standing on the pond perimeter. This would indicate extreme cases of seepage; however, limited amounts of seepage from the ponds may have remained unnoticed.

Sealant

Twelve questionnaires indicated that the ponds were sealed. Of these 12 ponds, 8 ponds were sealed with clay, 3 ponds were sealed with bentonite clay, and 1 pond was sealed with asphalt. Three of the ponds sealed with clay were reported to be retaining the water, and the remaining had obvious seepage. Preliminary results seemed to show a possible correlation of construction practice with water holding ability. The inital loading and weed problems appeared to have an effect on the sealant. This will be discussed under later sections.

Odors

Thirty-five of the 64 questionnaires divulged problems with odors. Distance and waste characteristics have been related to odor complaints in previous sections. The odors were prevalant, as was expected, in the spring of the year after the ice breakup, and the resulting change from anaerobic to aerobic operation. The duration of the time that noticeable odors were present varies from a few days to several months. Seven ponds had odor problems from less than 1 week, 10 ponds had odors from between 1 to 4 weeks, and 9 ponds had odors for longer than 4 weeks. There appeared to be a relationship of depth of pond to odor complaints in that 90% of the ponds with less than a two-foot depth reported odor problems. Odor complaints were, however, a problem at all depths.

Miscellaneous

Several operators mentioned problems associated with their specific stabilization pond. Among the most frequent were those associated with weeds and bank erosion. Several ponds had weed problems which were, in general, related to low liquid levels. Operators reported that in most cases pulling the weeds was the best solution to the problem because of regrowth after spraying or cutting. In several cases, weed growth appeared to promote seepage.

Questionnaires also indicated problems of wave erosion of the banks. These were generally reported in the larger ponds. Some operators had corrected this situation by rip-rapping the banks with oversize material. One operator reported that the inside banks of the pond were too steep to facilitate cleaning and weed removal.

Two communities reported that their ponds were of inadequate size for the waste produced. For one of these, the design population was significantly lower than the 1960 population and the community also had some industrial waste. The second community, in 1953 before most design recommendations had been developed, constructed a pond extremely close to the city, and had significant odor problems. This city was abandoning the pond and constructing a larger stabilization pond further away from the community.

For special construction or correction practices, two communities reported the use of drainage tile and one constructed channels to intercept the seepage.

Summary

The questionnaire results indicated several characteristics of the ponds and gave some idea of design problems. It was shown that a number of ponds exhibited seepage. This was evidenced by the number of ponds which had obvious seepage. It may be assumed that a number of ponds, other than those having obvious seepage, were also experiencing a large amount of water loss by seepage. This was evidenced by the number of ponds which did not overflow and by the ponds that had shallow operational depths. The location of ponds did not give adequate consideration in design to prevailing winds because ponds were located in all directions from the communities. In general, it was found that the ponds were located quite close to the communities. The factors of economics, gravity flow, land availability, and stabilization pond maintenance seemed to govern the location of the pond rather than the odor and groundwater pollution considerations. It appears to be extremely difficult to locate a pond at a distance of more than one-half mile from a habitation because of the density of farmsteads.

Seepage losses appeared to be related to the surrounding soil conditions, although seepage did occur with all types of soils. Gravels and sandy soils gave the poorest results, and clays gave the best. Even though several ponds were sealed, the majority of these ponds still failed to maintain an adequate water level. However, because some sealants did give satisfactory results, sealing should be considered partially successful.

The depth of the groundwater was found to be quite shallow in the vicinity of the ponds. Seepage poses a special problem because of groundwater contamination in these areas. Considering the surface ground slope, the ponds were generally found to be located downhill from the communities, and thus pollution of the groundwater may not have an immediate detrimental effect on the usage. The water quality change, however, may limit future usage.

Most ponds were used exclusively for domestic waste treatment, although some communities did use the ponds for combined treatment with industrial wastes. A number of ponds had odor problems which were prevalent in the spring. The duration of these odors varied from a few days to several months. Odors appeared to be related to the distance to habitation, the loading, and the depth of the pond. Other problems associated with the ponds were weeds, bank erosion, and inadequate size.

EVALUATION OF FIELD INVESTIGATIONS

Before specific ponds are discussed, some general observations can be made regarding the site visitations. The ponds were selected for visitation because they had indications of seepage or a sealant had been used. In some cases a sealant was utilized in an attempt to prevent seepage.

Two general site characteristics seemed to be the cause of the seepage problems. The first of these conditions was inadequate soil characteristics. Generally the seepage problem could be directly related to the surrounding soil conditions. Ponds located in sand or gravel type soils appeared to leak extensively. The second undesirable site characteristic was the elevation of the pond bottom with respect to the elevation of the surrounding land. The location of the pond bottom may have been significantly above or below the surrounding ground surface. Those located above the ground surface possibly caused a hydraulic head which accentuated the amount of seepage flow to the underlying groundwater or in cases even to the ground surface. Those located below the ground surface would have experienced problems of surface drainage into the ponds. Some ponds incorporated both of these undesirable characteristics by being located on the side of a steep sloping hill. In some cases it was observed that seepage water was present on the outside of the pond embankments. In general a pond by itself having seepage would be expected to have an influence on the surrounding groundwater.

Certain ponds located in pervious soils were sealed. Clay was found to be the most prevalent sealant used; however, construction practices, such as compaction, may possibly affect the degree of seepage prevention. For the majority of the ponds which were not sealed, it appeared that a general soil survey would have indicated that a sealant should have been used. Some installations, however, appeared to be located in impermeable soils, but after seepage was noted, additional soil studies indicated that permeable veins or layers were present.

The distance and direction from town and habitation varied considerably. It was found that the greater the distance between the populace and theponds, the less were the complaints. The odor complaints were generally in the spring of the year, although some ponds located close to the towns often had complaints in both the spring and summer. In some cases, topography compensated for distance by having the ponds located beyond hills. The direction in which the pond was located from the town usually was determined by the available land, its cost, and gravity flow rather than by prevailing winds or distance considerations. Interviews indicated that location of nearby habitation was considered for the exact location of ponds.

The depth to the groundwater table was found to be relatively shallow, only in limited instances was it estimated to be greater than 10 feet. The extent of chemical change of the groundwater was not determined in this study, although another study (22) has shown the change to be quite significant. Because of the very nature of the waste and the amount of seepage, it is safe to assume that the groundwater quality is changed to some degree. Seepage or lack of water level appeared to have encouraged weed growth which may have further increased the seepage. Observation and interviews give contrasting impressions that the seepage problems become either more extensive (probably from weed growth) or in cases appears to seal itself. The latter was found to a lesser degree, but may be a factor to consider. No wells were found to be located in the immediate vicinity of the ponds. Most wells were found to be over a quarter of a mile from the pond. The filtering and sorption characteristics of the soils would eliminate bacterial contaminants and a portion of the chemical pollutants. The surrounding land was generally used for agricultural purposes. Therefore, the water quality requirements for these uses would describe the significance of the pollutants that may be present.

Except for some odor problems, the operators generally had few complaints about the ponds. Although several operators recognized that the ponds were not adequately treating the waste, nevertheless the removal of the wastes from the community was being accomplished. It appeared that no adequate steps would be taken to obtain desirable treatment. Because of the lack of specific remedies, infrequent complaints, and the complacency of almost everyone concerned, solutions to many of the existing problems will probably not be forthcoming. Pond maintenance was found to vary greatly. It was found in communities which had interested operators that problems were reduced and pond treatment was better.

Ponds selected for the visitation are discussed separately because they experienced individual problems. Table 3 contains some information about eachpond visited.

Akaska

The 0.8 acre stabilization pond at Akaska was designed for a population of 90. The upper soil in the area of the pond was sandy-clay. However, the pond was constructed as a "dugout" approximately 10 feet deep. Although the underlying soil was not easily identified, it was obvious that the pond was located in a somewhat porous

Table 3. Stabilization Ponds Visited including Surface Area Data

Community	1960 Population	Design Population	Date Constructed	Cells	Cell size (acres)
Akaska	90	90	1960	1	0.8
Beresford	1794	1686	1955	2	8.5-8.0
Bowdle	673	860	1957, 1966	2	8.6-8.0
Castlewood	500	1500	1957	2	7.6-8.4
Lake Preston	955	1148	1962	2	7.0-7.0
Long Lake	109	110	1962	1	1.1
Milbank	3500	3400	1961	2	14.4-14.1
Mound City	144	160	1960	1	1.6
Murdo	783	930	1956	1	9.3
Summit	283	400	1959	2	3.6-2.1
Tabor	378	490	1956	1	4.9
Valley Springs	472	530	1955	2	3.8-2.0
Volga	780	2100	1959	3	7.0-7.0-7.0
Webster	2409	3200	1959	2	16.9-16.5
White River	397	440	1963	1	5.0

soil because of the high seepage rate. The pond was sealed with bentonite. It appeared that insufficient flow to the pond plus seepage caused weed growth which resulted in additional seepage and failure of the seal.

The absence of water made the pond ineffective as a treatment device. The odor problems were associated with the proximity of the pond to the town plus the fact that there was almost no water in the pond. The slope of the ground in the vicinity of the pond was away from the community and towards a river. Although the pond seepage would degrade the groundwater quality, it is doubtful that it would affect the usage of the surrounding water for domestic purposes because of the topographic gradient.

The major factors that adversely affected the operation and location of the pond were the poor soil, the inadequate distance from the town, the weed growth, a minimum hydraulic loading, and poor pond bottom elevation. The advantages of the location are that it afforded gravity flow and a good topographic gradient. However, in view of the pond's construction features and location very near the community, it is doubtful that the pond will ever be fully acceptable.

Beresford

The two-celled stabilization pond of 8.5 and 8.0 acres at Beresford was designed for a population of 1686 and served a 1960 population of 1794. The pond location in general was good. The distance to town and habitation was great enough to minimize most odor and nuisance complaints. The ponds were located at an elevation slightly above the ground surface preventing surface water inflow, and they did not provide a large hydraulic head.

The ponds were located near a creek bed and soil observations indicated sandy soil. This fact was initially recognized and the ponds were sealed with a clay layer. However, the ponds still had apparent seepage to the stream bed and some surrounding farm land. Slight weed growths were observed, especially in the second cell, which may have been a result of seepage and/or partially caused by seepage. To partially correct the seepage problem, drainage tile was installed to remove the lateral seepage. Thus the drainage tile compensated for part of the seepage problem; however, the possibility of groundwater contamination still remains.

The ponds showed the advantages of proper distance and demonstrated the use of drainage tile to eliminate some problems caused by seepage. Other advantages of the location were the pond bottom elevation and the satisfactory land gradient. The importance of soil studies was demonstrated, and it was illustrated that sealants in themselves are not always successful. The pond, despite the seepage, appeared to give satisfactory treatment.

Bowdle

The Bowdle stabilization pond was designed for 860 population equivalents and served a 1960 population of 673. One cell was constructed in 1957. This cell was located in a sandy-clay type soil which was underlain by a sandy soil. Because of the soil characteristics, the pond was sealed with clay. Because of the high hydraulic loading plus the good sealing properties of the clay, a considerable volume began overflowing to an adjacent creek. In 1966 the city built a second cell of approximately 8.0 acres. To date the second cell has been large enough to prevent any overflow from the installation, and both cells appear to be giving satisfactory treatment. Complaints were limited because of the sufficient distance to the town and most habitations. Surface runoff and high hydraulic gradient were prevented by locating the pond bottom just above the surrounding ground elevation. The pond was giving satisfactory results because of the sealant, satisfactory distance, topographic gradient, and pond bottom elevation.

Castlewood

The stabilization ponds serving Castlewood were constructed in 1957 for the treatment of domestic and creamery wastes. The 7.6 and 8.4 acre ponds were designed for a population equivalent of 1500. Shortly after construction the creamery closed and the ponds then served a 1960 population of 500. The ponds have been dry except for a small area near the inlet of one cell.

The ponds were located near a river in permeable soil. A gravel or sand pit was located directly adjacent to the pond. The ponds were not sealed and the resulting seepage prevented water from accumulating in the pond. Problems of weed growth and odors resulted. Odor complaints also resulted because of the proximity of the pond to the community. The topographic gradient was toward the river and away from town. Because of the amount of seepage, deterioration of the surrounding groundwater quality would be expected.

The major factors that contributed to the failure of the Castlewood pond were soil conditions and low hydraulic loadings, although distance considerations and weeds appear to have had additional adverse effects on the satisfactory acceptance of the pond. In view of the soil conditions in the general vicinity, this site appears acceptable only if a successful sealant could have been placed in the pond. Since the wastewater required pumping, the only advantage of this site appeared to be low land costs and the availability of the land.

Lake Preston

The two-celled installation (7.0 and 7.0 acres) built at Lake Preston in 1962 served a 1960 population of 955 plus an amount of waste from a creamery and a local slaughtering house. The pond was located in a nearly-dry lake bottom which has a silty-clay type of soil. The pond was sealed with yellow clay; however, some seepage had occurred, but the problem reportedly had ceased. It is unknown whether the sealant or the original soil conditions prevented seepage from the pond. A slight amount of seepage was evident during the visitation, although it was not great enough to cause low water levels. The seepage would not present a groundwater quality problem, because of the gradient and location in the lake bottom.

The pond was located below a hill away from a major portion of town. Although odors were reported, the hill provided somewhat of a barrier, and thus partially compensated for the lack of distance between the pond and the town. The ponds were adequately diked to prevent surface water influent and operation was excellent. Although the pond was reported to exhibit seepage, the problem was minimum. The advantages offered by the soil conditions, the sealant, and the topography all appeared to contribute to the success of the pond.

Long Lake

The one-celled stabilization pond (1.1 acre) at Long Lake was built in 1962 and served a 1960 population of 109. The pond was located in a coarse sand type of soil. To correct for the soil conditions, the pond was sealed with a clay layer, but the results showed little success. This may have been caused by the low initial flow to the pond; weed growth occurred which probably caused seal breakage and compounded the seepage problem.

The pond was located on a steep slope allowing surface water to enter directly from two directions. Seepage was observed on the opposite sides behind the dikes. The pond was located extremely close to the town and individual habitations. Again the hill appeared to compensate for any odors produced. A field well and a farm were located close to the pond and in the downstream direction of the groundwater flow. Too much emphasis appears to have been placed on land availablity and gravity flow for this pond. Almost every design characteristic for location seems to have been neglected. The disadvantages of the soil conditions, the water table conditions, distance to the town, and poor pond bottom elevation have made the pond inactive as a treatment device. It would be expected that present problems will continue in the future unless changes are made.

Milbank

The two-celled (14.4 and 14.1 acres) stabilization pond at Milbank was constructed in 1961 and treated the wastes from a 1960 population of 3500 plus some industrial waste. The pond was apparently located in clay. After the pond was constructed, seepage was noted, and additional soil tests showed that gravel veins were present. Because this was unknown at the time of construction, no sealant was used.

The ponds are located on a higher elevation than the surrounding land. Complaints were received that the seepage was flowing to the surrounding agricultural land as well as to the stream and groundwater. Tile was installed by the city to intercept the seepage to the surrounding ground surface; however, seepage to the groundwater probably still occurs. The pond was located relatively close to the city and some surrounding farms. Some weed problems and odors were present at the pond. Preliminary studies (22) indicate that the pond seepage may be significantly changing the quality of the adjacent groundwater. The pond despite the large quantity of seepage and several undesirable location characteristics still appeared to function satisfactorily as a treatment unit. The pond problems encountered point out the importance of thorough soil and elevation investigations. The use of drainage tile to remove seepage was well illustrated.

Mound City

The 1.6 acre stabilization pond at Mound City was built in 1960 and served a 1960 population of 144. The pond showed signs of extensive seepage and extremely low water elevations. The pond was located in a coarse to fine sandy soil in a dry lake area. To prevent seepage the pond was lined with bentonite. The pond reportedly has never satisfactorily held water. Low water levels were probably caused by the high seepage plus a low hydraulic loading.

Weeds were prevalent and possibly caused greater seepage. The pond was located at a sufficient distance and gradient from the town and farms to eliminate most complaints of nuisance and odors.

The pond influent probably seeped directly to the groundwater table and outward to a nearby swampy area. This likely changed the surface and groundwater qualities, although the usage appeared to be only for surrounding stock and wildlife watering. The pond location characteristics of distance and topography partially off-set the seepage problem caused by the soil conditions, weed growth, and low initial flows. Nevertheless, the pond was inoperative as a treatment device, and was probably affecting the groundwater quality.

Murdo

The one-celled stabilization pond at Murdo was built in 1956 and served a 1960 population of 783. The pond had some obvious seepage to the surface at two sides of the embankment. This area was significantly below the level of the pond bottom. The seepage plus some overflow was intercepted by a creek. The area surrounding the pond was used for pasture.

The pond was located in a clay type of soil but underlain by a porous material, was not sealed, and was located a sufficient distance from the town to counteract any nuisance and odors produced. In addition the gradient of water flow was away from the city. The pond appeared to be functioning satisfactorily as a treatment unit.

With the use of the surrounding surface water for livestock watering and the land for agricultural use, possible contamination by seepage may become a problem in the future. Although the quantity of seepage was not great enough to cause pond failure, better soil selection for sealing or a different pond elevation may have solved the problem of seepage. The location characteristics had slight advantages in the distance and gradient conditions, but a somewhat undesirable elevation of the pond bottom. In general, the location of the pond was good, but by utilizing soil selection or elevation change the pond could have been improved.

Summit

The two-celled stabilization pond (3.6 and 2.1 acres) at Summit was built in 1959 and served a 1960 population of 283. The ponds were located in a sandy soil. Soil selection was used, and the ponds did hold some water. The two cells were operated in series with the second cell at a lower elevation than the first. Seepage loss was evident in both cells, and because of the operation and seepage the water level in cell two was quite low. Weed growth appeared in the cells. In addition to the seepage, low hydraulic flow may contribute partially to the low liquid levels.

The ponds were located in a relatively level area at a sufficient distance from the town and habitance to minimize most odor and nuisance problems. The advantages of distance and some soil selection appeared to overcome the problems caused by the undesirable soil characteristics. The result was a reasonably satisfactory operating pond.

However, the Summit ponds probably would have functioned better had they been sealed or had better soil selection been employed.

Tabor

The one-celled stabilization pond at Tabor was built in 1956 and served a 1960 population of 378. The pond was located in a clay soil with possible sandy characteristics underlaying the clay. Seepage problems had occurred during the early operation of the pond. Although there was evidence of some seepage, the pond was operating at a satisfactory liquid level.

The Tabor pond had many typical design characteristics including a rectangular shape, adequate distance from homes, and desirable soil characteristics, but had associated problems including odors in the spring, slight weed growth, and seepage loss. The pond was located at an elevation above that of an adjacent dry creek bed. Seepage was probably to the groundwater and towards the low creek bed area. The surrounding land was used for pasture and haying.

The pond, in general, was operating satisfactorily and several desirable site characteristics including distance, soil conditions, and topographic gradient, eliminated large problems caused by the pond. With possible sealant or soil selection, different elevation factors, and/or possibly filling the pond immediately after pond construction, present problems may have been eliminated.

Valley Springs

The two-celled (3.8 and 2.0 acres) Valley Springs stabilization pond was built in 1955 and served a 1960 population of 472. To date only the smaller cell has been used and the observed operating depth was two feet. The pond was located near a creek in a sandy soil overlain by black dirt. Although porous material was evident, no sealant was placed in the pond and large amounts of seepage resulted. This seepage flowed to the groundwater and the creek bed.

The distance from the community to the pond was minimal according to recommendations, but the topography in the area limited the odor and nuisance complaints. Odors were clearly noticeable near the ponds during visitation, although not noticeable in the community. Weed growths were quite significant in the operating pond, but no surface runoff or large hydraulic head was evident. The general topographic gradient was away from the community and the surrounding land was used for hay and pasture. Although the topography minimized the complaints resulting from the pond, the soil conditions plus low hydraulic flows limited the pond in its functioning as a treatment unit.

Volga

The Volga stabilization pond consists of three 7-acre cells constructed in 1959 to handle the wastes from a domestic population of 850 plus a creamery. One cell of the pond was operating with a sufficient liquid depth, a second cell had a liquid depth estimated at two feet, and the third cell was completely dry. The pond was located in the flood plain of the Big Sioux River, and the soil in the area was fine to coarse sand. The cell which was operating at a satisfactory depth had been sealed with an asphalt sealer while the remaining two cells contained a clay layer. However, preliminary testing (22) indicated that the full cell was leaking. Low operating depth was probably caused by seepage, although low hydraulic loading may have also occurred.

To correct the problem of seepage to the surrounding land, a channel was dug along the periphery on one side of the installation to intercept the outward seepage. This also drained a swampy area adjacent to the pond. This water was discharged to the Big Sioux River. Weed growth was evident in the two cells with inadequate liquid levels. Pond odors which have drawn complaints were probably a result of the high organic loading from the creamery.

The pond was located a sufficient distance from the community and surrounding farms to minimize problems. Although the change in quality of the groundwater was found to be significant (22) the adjacent usage did not appear to be affected. Land availability and economic advantages were obviously significant factors in the location of the pond.

Webster

The two-celled (16.5 and 16.5 acre) stabilization pond at Webster was built in 1960 and served a 1960 population of 2409. Because of the size of the ponds, the soil characteristics may have varied throughout the ponds. Both coarse sandy soils and clay soils were found in the area. The pond had not been sealed although some soil selection was apparently made.

The pond had ditches around all but one side. Evidence of seepage was found on the downhill side. The extent of the quantity of seepage was not apparent because land runoff also entered this ditch. Groundwater quality may have been influenced by seepage although the direction of groundwater flow was away from the community.

The ponds were located on the edge of town quite close to nearby habitations. The community was upstream from the apparent groundwater flow. Odor problems were reported and slight weed growth was observed. The pond appeared to be providing satisfactory treatment although there was no observed overflow. Better use may have been made of soil selection, and distance should probably have been allowed for future expansion of the community. The advantages of soil selection and gradient made this pond successful from a treatment viewpoint; however, lack of distance from the community may cause future problems.

White River

The White River pond consists of a single 5-acre cell constructed in 1956 and served a 1960 population of 397. The unit had been internally diked in an attempt to maintain a water level; however, the total pond is now being used for treatment. The pond is located in a shale type soil, although surrounding land showed signs of the presence of sandy soil. Excessive seepage was observed following construction, and clay was then mixed into the pond bottom. Observed liquid depth, however, was approximately two feet.

The pond was located on an extremely long, steep-sloping hill allowing the influent of surface water and causing a high hydraulic head. Water was observed to be standing on the downhill side of the pond.

The pond was located quite close to the town, although topography appeared to minimize the odor problems. Excessive weed growth was apparent and probably was influenced by the low water level and the construction of the interior dikes. The gradient was away from domestic withdrawal;

however, the surrounding land was used for pasture land.

The pond failure can be attributed to the many undesirable characteristics including soil conditions, distance to town, pond bottom elevation, and the constructed interior dikes. The use of a sealant and the location of a hill between the pond and the town were not adequate to compensate for these undesirable characteristics.

METHODS FOR POND SITE EVALUATION

It has been observed from this study that stabilization ponds can be adapted to many conditions, and that various conditions will warrant different design criteria. Some installations have performed satisfactorily while operating under conditions which at first would appear to be undesirable. Others are operating poorly under somewhat ideal conditions. Because of the wide variety of conditions and the large number of variables, adherence to strict design criteria appears to be undesirable. But because the stabilization pond is dependent upon many variables, and because of the permanence of the installation after it has been placed into operation, a study to establish the location of the pond should evaluate all of the various factors. Defining and analyzing these factors has become a problem, and thus in many cases because of the limited funds and time, or lack of sufficient interest, the stabilization pond site has been selected on a hit or miss basis. A preliminary site survey must, however, be inexpensive because one of the main uses of the stabilization pond is to make wastewater treatment economically practical for small communities, small industries, and individual farmers.

With the aid of the data collected from the sites visited, and with the ideas obtained from the literature, a number analysis method and nomograph were developed to assist in pond site evaluation. The primary considerations in pond location are the satisfactory treatment of the waste and protection of the surrounding environment. This proposed method must not be taken as a strict set of rules or criteria, but rather as a guideline for the evaluation of a site for a preliminary stabilization pond. However, a detailed study, including a complete engineering and economic analysis must be made prior to the final selection of the location of the sewage treatment facility.

The problem of site evaluation will be analyzed from two different views: (a) to determine the general suitability of the location, and (b) to determine the treatment for the pond bottom to minimize problems associated with seepage.

Location Suitability

The suitability of a potential pond location may be analyzed by using Table 4. A numerical rating is assigned for each pond condition and the sum of these numbers will afford an evaluation of the suitability of the location. An adverse condition is indicated by

TABLE 4

Preliminary Location Suitability Analysis

Gravity Flow	Prevailing Winds* (degrees)	Distance to Town (miles)	Depth to Groundwater (feet)	Slope of Ground**	Soil	Nature of Waste	Ground-water Uses	Points
Total Pumpage	0	0	0	Adverse	Gravel	Toxic	Multiple	0
	30	$\frac{1}{4}$	10	Level	Sand	Raw Sewage	Individual Domestic	1
	60		20	Favorable	Silt	Primary Sewage	Irrigation	2
Total Gravity	120	$\frac{1}{2}$	50		Clay	Storm or Cooling Water	None	3
	180		500					4
								5
								6
		1						7

*Degrees shown are from the community toward the pond relative to the prevailing wind direction.

**Adverse is towards a point of withdrawal and favorable is away from a point of withdrawal.

a low numerical value, and consequently, the higher the numerical sum the better the site. The factors used in the analysis can be readily determined by direct observation or estimation, and from records kept by various agencies such as the weather bureau.

For example, a pond having the conditions listed below would be evaluated as follows:

a)	total pumpage	0 points
b)	pond displaced 60° from prevailing wind	2 points
c)	½ mile from the town or habitation	3 points
d)	10 feet above the groundwater table	1 point
e)	has a level slope	1 point
f)	has a silty soil	2 points
g)	planned for raw sewage	1 point
h)	groundwater used for individual domestic supplies	1 point
	Total	11 points

However, before the evaluation can be completed by this method, other factors must be considered. For instance in evaluating distance, groundwater users should be considered. A separate distance point value should be established for each habitation or community that may be influenced by the pond location. Of these evaluations, the one having the minimum point value would then be utilized for determining the site rating.

A general conclusion can now be drawn concerning the suitability of the above site by comparing the sum of the points with the evaluations shown in Table 5.

TABLE 5

Final Location Evaluation

Total Points	Conditions
Below 11 points	Unacceptable
11 to 15 points	Questionable or marginal
16 to 18 points	Good
Above 18 points	Excellent

It may be observed from Table 5 that below 11 points the site would be considered unacceptable and a different location should be sought. Between 11 and 15 points the location would be marginal. Although this site may be acceptable, other sites should also be investigated. However, some adjustments of the factors of influence may make the site more desirable. Appendix D offers some suggestions when undesirable characteristics are found. Although some precautions may still be needed, a suitable site for a pond would be indicated by a range of 16 to 18 points. It is felt that ponds in this point range will perform satisfactorily provided that some precautions are taken. A point total above 18 indicates a location where minimum problems would be expected.

Thus, in the preceding example a total of 11 points would indicate that this particular site is marginal for the location of a stabilization pond.

Nomograph for Suggested Treatment of Pond Bottom

Because of the critical nature of maintaining an adequate water level and preventing seepage, site analyses with respect to the treatment of the pond bottom are made after a site has been selected. The nomograph, Figure 4, affords an evaluation of a site with respect to the four factors of soil conditions, water conditions, nature of waste, and uses of water. This evaluation will allow the selection of a method for pond construction to reduce the contamination potential of a site.

Three of the four factors shown in Figure 4 are self-explanatory, while the fourth factor of groundwater conditions is determined from Table 6 which was derived from an article by Harry LeGrand (31). The groundwater condition is obtained from an evaluation of the three factors of water table depth, water table gradient, and distance to a point of withdrawal.

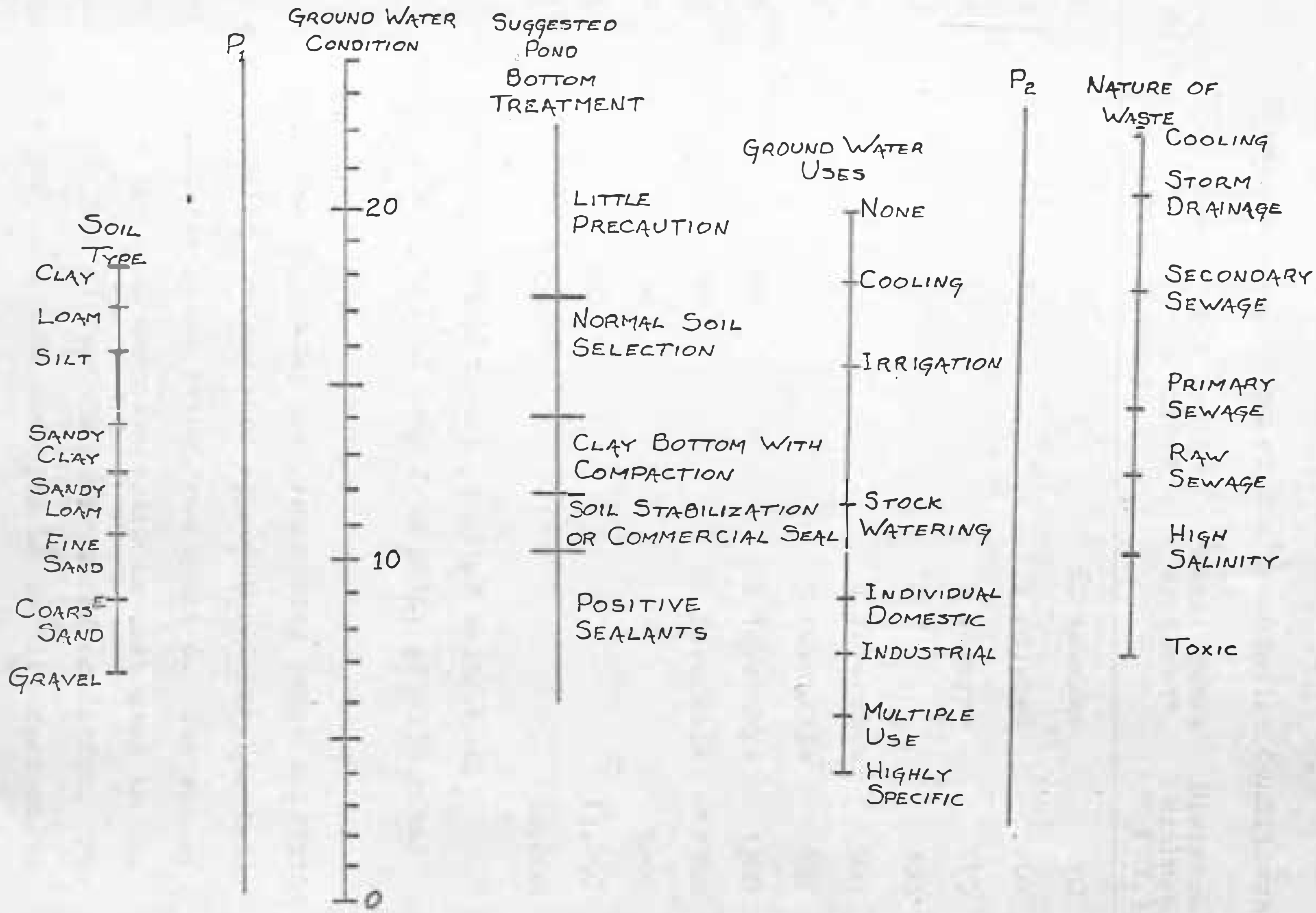

Figure 4. Suggested Preliminary Design for Pond Bottom

TABLE 6

Numerical Evaluation of the Groundwater Conditions

Point Value	Water Table Depth (ft. below proposed pond bottom)	Water Table Gradient*	Distance to Withdrawal (ft.)
0	0	60 adverse	0
1	10	12 adverse	100
2	15	5 adverse	175
3	22.5	0	300
4	30	2 favorable	500
5	40	5 favorable	850
6	60	8 favorable	1300
7	80	60 favorable	2500
8	100		5200
9	300		13,000
10	1000		52,000

*adverse--gradient toward point of withdrawal

favorable--gradient away from point of withdrawal

The number depicting the groundwater table condition is determined by finding each appropriate characteristic and obtaining its point value from Table 6. The sum of the numbers for each characteristic is then used in the nomograph (Figure 4) for the water table condition. For example, a proposed pond which is to be 12.5 feet above the existing water table would receive 1.5 points. If the gradient was found to be zero, it would receive 3 additional points, and if the nearest use of the water was 1000 feet from the site, it would receive 5.3 extra points. The total of 9.8 or 10 is the number used in the nomograph for water table conditions.

The nomograph is used by first drawing a line joining the soil conditions and groundwater conditions for the pond location, and marking the crosspoint on pivotline P_1. The same is done with groundwater use and nature of waste, and marking the crosspoint on pivotline P_2. The two pivot points are then connected and the treatment condition is read from the nomograph.

If a variety of these four controlling conditions exist as a result of considering groundwater users of different locations, a treatment condition for each case should be used. The nomograph is only intended to serve as a guide and is subject to various limitations. The numerical evaluation of the location and the suggested treatment for the pond bottom of each of the sites visited is shown in Appendix E.

Limitations of the Analysis

It must be cautioned that this system has certain limitations and it is intended only as a guide for incorporating the many variables that may be involved.

Minimum standards should still be imposed for site selection. These would include a minimum distance of one-quarter mile, a minimum depth above the water table of five feet, and the distance to nearest withdrawal as set by public health authorities. Although it would be possible to have a site in the middle of the community with such characteristics that the analysis would allow it to be acceptable, this location would obviously be rejected.

A number system was used only for convenience to obtain a relative evaluation. The numbers are all arbitrary having been developed by visitation to actual stabilization pond sites and by incorporating certain literature values. Because the values were obtained and tested on ponds in South Dakota, certain changes may have to be made for adaption of the system to another state, although basically the system should be valid for most areas.

Because so many of the factors are based on estimates or judgments, it is reasonable to assume that other investigators could obtain different results. Also, although definite ranges have been placed for the treatment of the pond bottom, conditions may actually vary. That is, two sites--one evaluated to be just below the dividing line between two categories, and the other just above the dividing line--may actually represent equal pond bottom treatments. In using these systems the investigator may feel that some characteristics warrant more attention than others and may, therefore, alter the suggested point values accordingly. However, this must be done objectively and not only to make a location acceptable.

Thus with a short, simple, and relatively inexpensive preliminary survey, the suitability of a site may be estimated. Use of the system does not guarantee that a site selected and treated as indicated would result in a suitable installation, but it is hoped that its use will stimulate pertinent analysis of the contributing factors which will in the end result in a properly operating pond that will not cause contamination problems.

Procedure for Selection of a Site

The various factors to be used in this organized method of site selection can be determined to varying degrees of accuracy. Although additional details, other than those required for the minimum analysis, will entail additional costs, the information obtained would possibly improve the pond results and acceptance. A possible method of site analysis is described below. It pertains to site selection only, and consequently does not consider organic loading or the design of the physical features of a pond.

1. Determine the waste characteristics. These can be obtained from the present type of waste or the expected type of waste which the pond is being designed to treat. This analysis may range from a general survey of the waste contributors to a detailed laboratory analysis. Normally it is felt that a minimum field survey would be sufficient, although, depending on the various other factors and the expected waste, some chemical analyses may be desirable.

2. Potential pond sites approximately one-half mile or greater from the community should be located. Consideration must be given to the direction that the community is expanding and to any nearby habitation. Potential site areas should be located on relatively level ground, and have a sufficient availability of land. Prevailing winds may be determined from a weather station or large airport. The pond should be located near a watercourse, if possible, to accept pond overflow.

3. Soil conditions at the sites should be examined. This factor can vary from rough estimations to a highly detailed study. Minimum analysis would include several test holes slightly below the expected pond bottom to obtain a general soil analysis. Larger ponds would require more test holes. Because soil analysis is extremely important, consideration may be given to having laboratory

soil testing and field permeabilities taken. Again the additional testing will entail additional cost, but will possibly give more satisfactory results.

4. The water table normally follows the slope of the surrounding land and the direction can thus be estimated if no large withdrawals or other factors are located nearby. Depths to the groundwater can be determined from borings or nearby wells, and the flow direction and gradient may be obtained by measurement of water table elevations. Points of withdrawal and use must be considered.

5. Gravity flow to the site can be determined by estimation and direct observation, or by engineering surveys.

6. After these characteristics are obtained, evaluation of the sites can be made with the aid of the previously presented methods. If the two sites are approximately similar, economic evaluation of the sites should be made.

Although the minimum study could be accomplished in a relatively short time, it is felt that with proper organization and consideration of all the factors involved, a reasonably good site selection would result.

SUMMARY AND CONCLUSIONS

It was observed during this study that many stabilization ponds were satisfactorily treating wastes without experiencing significant problems. However, at many other ponds various problems have occurred, including odors, weeds, and seepage. Many of these problems can be related to site factors including soils, distance, and relative elevation. The major reason that ponds experienced failure was because of the lack of proper site selection. The following conclusions were drawn from this study.

1. A preliminary site study must be made on all potential sites. Sufficient data must be gathered and examined in an organized manner, and engineering judgment must be utilized to determine the suitability of the site. The preliminary site selection is probably the most important aspect for the successful utilization of a stabilization pond.

2. The overall economic influence must be considered as an important factor in stabilization pond location, although it does not in itself affect the pond performance. The economic influence would include initial cost, operational cost, change in land values, and cost required in making changes should problems develop. In the past it appears that too much

emphasis has been placed on inital land costs and gravity flow for pond location. The result has been unsatisfactory pond performance, nuisance conditions, and/or additional investments to correct the problem.

3. The two principal factors contributing to pond failure were found to be undesirable soils, and poor elevation of the pond bottom with respect to the surrounding ground elevation. Special construction practices including pond sealants and drainage tile, appear to partially compensate for some undesirable conditions; however, problems caused by the undesirable conditions were not completely overcome.

AREAS OF FUTURE STUDY

This investigation gave some indications for additional areas of research. Below are listed some of these areas.

1. Detailed study could be made of the extent of the seepage and the allied problems related to the seepage. The research could be expanded to include the movement and removal of contaminants in different types of soils under varying conditions.

2. Greater development of the site selection method could be made. Although this requires additional refinement and definition, it is firmly believed that the analysis must remain relatively simple. This will eliminate detailed studies which in many cases, although desirable, may be prohibitive.

3. The area of sealing, soil selection, and construction methods appears to be almost unlimited for future study for stabilization pond design.

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APPENDIX A

Communities Returning Questionnaire

Akaska
Baltic
Belle Fouche
Beresford
Big Stone City
Bison
Bonesteel
Bowdle
Britton
Bryant
Buffalo
Burke
Canpova
Canton
Castlewood
Colome
Colton
Conde
Cresbard
Draper
Eagle Butte
Edgemont
Estelline
Faulkton
Ft. Pierre
Garretson
Gettysburg
Groton
Jefferson
Kadoka
Kennebec
Lake Preston
Lennox
Long Lake
McIntosh
McLaughlin
Madison
Milbank
Morristown
Mound City
Murdo
New Effington
New Underwood
Orient
Plankington
Pollock
Presho
Redfield
Sisseton
Summit
Tabor
Valley Springs
Veblen
Volga
Wagner
Wall
Watertown
Webster
Wessington
Wessington Springs
White River
Badlands National Monument
Custer State Park
(two locations)

APPENDIX B

Stabilization Pond Questionnaire

Town_______________ Operator reporting_______________

Depth of Pond___________ Does it overflow_______________

Does the depth of the pond vary throughout the year__ amount___

Distance from town_______ Direction from pond____________

Distance from nearest habitation__ Direction from pond____

Direction ground slopes in area of pond_______________

Type of soil pond is located in (gravel, sand, silt, clay, etc.)____ Depth in general area to groundwater___________

Types of wastes placed in pond other than domestic sewage (dairy waste, slaughtering wastes, etc.)__________

Does any water other than wastes run into the pond_______

Is there any apparent seepage_________________________

Was any sealant or special material placed in pond to prevent seepage__________________

If so, what______________________

Design engineer, if known_______________________________

Contractor, if known__________________________________

Any odor problems___ Approximate amount of time per year__

Other problems____

Other comments (use back if needed)

APPENDIX C

Questionnaire Summary

Number of Ponds Reported for Each Category

A. Number of replies: 64

B. Pond depth

a) 0-2 feet	10
b) 2-3 feet	9
c) 3-5 feet	37
d) over 5 feet	8

C. Pond depth fluctuation throughout the year:

a) 0-$\frac{1}{2}$ foot	34
b) $\frac{1}{2}$-1 foot	10
c) 1-2 feet	12
d) over 2 feet	8

D. Do the ponds overflow:

a) Yes	29
b) No	23
c) Partially or temporarily	12

E. Distance to town:

a) Within $\frac{1}{4}$ mile	23
b) Between $\frac{1}{4}$ and $\frac{1}{2}$ mile	20
c) Between $\frac{1}{2}$ and 1 mile	16
d) Over 1 mile	5

F. Direction to town:

a) N	5
b) Ne	10
c) E	7
d) SE	7
e) S	9
f) SW	5
g) W	10
h) NW	11

G. Distance to nearest habitation:

a)	Within ½ mile	38
b)	Between ¼ and ½ mile	15
c)	Between ½ and 1 mile	11
d)	Over 1 mile	0

H. Direction to nearest habitation:

a)	N	11
b)	NE	8
c)	E	8
d)	SE	5
e)	S	8
f)	SW	4
g)	W	8
h)	NW	12

I. Direction ground slopes in area:

a)	N	9
b)	NE	4
c)	E	11
d)	SE	9
e)	S	7
f)	SW	4
g)	W	10
h)	NW	3
i)	Level	5
j)	No answer or insignificant	2

J. Type of soil:

a)	Sand	6
b)	Gravel	2
c)	Clay	20
d)	Gumbo	5
e)	Sand and gravel	2
f)	Sand and clay	5
g)	Sand and gumbo	2
h)	Gravel and clay	4
i)	Shale and gumbo	3
j)	Clay and gumbo	2
k)	Clay and shale	1
l)	Clay and silt	2
m)	Loam	1
n)	Slough bottom	1
o)	Soil rock and clay	1
p)	clay and loam	1

Type of soil, continued

q)	Clay and loam	1	
r)	Silt gumbo	1	
s)	Sand, gravel, and clay	1	
t)	Unknown	1	

K. Depth to groundwater:

a)	0-10 feet	22	
b)	10-20 feet	31	
c)	20-50 feet	5	
d)	Over 50 feet	6	

L. Waste other than domestic:

a)	Dairy	11	
b)	Slaughtering	18	
c)	Laundry	3	
d)	Other	5	
	1. Storm drainage		3
	2. Sausage		1
	3. Poultry		1

M. Other pond water:

a)	Other influent to pond	17	
b)	Small amount of other drainage	4	

N. Seepage:

a)	Obvious seepage	25	
b)	Some seepage	8	

O. Sealants used:

a)	Clay	8	
b)	Bentonite	3	
c)	Asphalt	1	

P. Odor Problems: 35

Q. Time and length of odors

a)	Spring	24	
b)	Length of odors		
	1) less than 1 week	7	
	2) 1 to 4 weeks	10	
	3) greater than 4 weeks	9	

APPENDIX D

Alternatives to Modify Marginal Sites

If undesirable characteristics exist, the following may aid in determining what modifications can make the site more suitable.

Gravity Characteristics--choose site with desired characteristics,

Prevailing Winds--choose site with desired characteristics, increase distance, and/or choose site with desired topography,

Distance--add a desired amount of distance, and/or choose site with desired topography,

Gradient--choose alternate site, and/or make artificial gradient by using drain tile or surface channels,

Soil--choose alternate site, seal pond, and/or use construction practices to eliminate undesirable soils,

Distance to Groundwater--choose alternate site and/or seal pond to ensure minimum seepage,

Nature of Waste--eliminate undesirable waste entering pond, and/or pretreat the waste,

Uses--limit uses of surrounding water and land, and/or require treatment of water before use.

APPENDIX E

Location Analysis and Pond Bottom Treatment of Sites Visited

Pond	Location Analysis	Suggested Pond Bottom Treatment
Akaska	12	Clay bottom with compaction
Beresford	13	Clay bottom with compaction
Bowdle	13	Clay bottom with compaction
Castlewood	9	Commercial sealer or soil stabilization
Lake Preston	12	Clay bottom with compaction
Long Lake	10	Commercial sealer or soil stabilization
Milbank	12	Clay bottom with compaction
Mound City	13	Commercial sealer or soil stabilization
Murdo	13	Clay bottom with compaction
Summit	13	Commercial sealer or soil stabilization
Tabor	12	Clay bottom with compaction
Valley Springs	12	Clay bottom with compaction
Volga	12	Commercial sealer or soil stabilization
Webster	12	Clay bottom with compaction
White River	11	Commercial sealer or soil stabilization